A W-BAND CHANNELIZED MONOLITHIC RECEIVER*

G. L. Lan, J. C. Chen, C. K. Pao, and M. I. Herman
Hughes Aircraft Company, Microwave Products Division
Torrance, California 90509-2940

R. E. Neidert
Naval Research Laboratory, 4555 Overlook Ave.
Washington, D.C. 20375

ABSTRACT

Several monolithic integrated circuits with state-of-the-art performances have been successfully developed for a W-band (75 to 110 GHz) channelized monolithic receiver. The receiver comprises one four-channel multiplexer, four balanced mixers, four IF amplifiers, and four local oscillators. All will be monolithically integrated into only three chips. This paper reports on the design, fabrication, and performance of each monolithic component and describes the complete W-band four-channel receiver integration.

INTRODUCTION

The need to develop wideband receivers for use in millimeter-wave radar, communication, and surveillance systems is rapidly increasing. Although high-performance receiver components fabricated in the conventional waveguide or hybrid integrated circuit structures have been demonstrated at millimeter-wave frequencies, the use of these components in systems for tactical or communications applications is often hampered by the excessive expense incurred in the fabrication of precision machined parts, and labor-intensive assembly of the waveguide and the hybrid integrated circuit structures.

To reduce the cost, size, and weight of receiver components, monolithic technology has been widely used for components and subsystem fabrication at microwave frequencies. As the frequency increases to the millimeter-wave range, monolithic technology becomes more attractive because the size of both lumped and distributed circuit elements becomes smaller.

In this paper, we describe the systematic development of a W-band (75 to 110 GHz) channelized monolithic receiver. This includes the design, fabrication, and performance of each monolithic integrated circuit component and the complete receiver integration. This is the first W-band four-channel receiver using only three monolithic chips at the time of its completion, which represents the highest degree of either component or functional integration ever achieved at this frequency.

Receiver Design

The objective of this work was to develop technologies for the fabrication of low cost, high performance, uniform monolithic modules that can be integrated into a 75 to 110 GHz monolithic receiver front end. Figure 1 shows the block diagram of the receiver module. It consists of a four-channel multiplexer, four balanced mixers, four IF amplifiers, and four Gunn local oscillators. All will be monolithically fabricated on only three chips (a four-channel downconverter chip and two dual-channel local oscillator chips). The details of the monolithic components development and the complete receiver integration follow.

Four-Channel Monolithic Multiplexer

The purpose of a multiplexer is to divide the frequency into a number of channels, which may be continuous (adjacent in the frequency band) or separated by guard bands. In wideband EW receiver applications, the role of the multiplexer is critical, because it will minimize the mixer single-tone intermodulation distortion products that are the main culprit in causing false target detection. Figure 2 shows the complete W-band (75 to 110 GHz) four- channel multiplexer fabricated on a 4-mil thick GaAs substrate. Each channel of the multiplexer consists of two Lange couplers and two parallel-coupled bandpass filters. The termination port in each channel is a TaN 50-ohm surface resistor connected to a quarter-wave open stub. The performance of the multiplexer is excellent. As shown in Figure 3, the average insertion loss of each channel is approximately 5 dB and the rejection is better than 25 dB at approximately 3 GHz away from the passband.

Ion-Implanted W-band Monolithic Balanced Mixers

Four W-band monolithic broadband balanced mixers covering frequency ranges from 75 to 110 GHz have been developed for each of the four channels. The mixers use all ion implantation techniques and are completely compatible with GaAs MESFET based monolithic integrated circuit fabrication. Figure 4 is a photograph of the fabricated mixer chip. A typical conversion loss from 6.8 to 10 dB and DSB noise figure from 6.5 to 10 dB were measured over an RF frequency range of over 13 GHz with 10 dBm LO drive (see Figure 5).[1]

*This work is supported in part by the Naval Research Laboratory under Contract N00014-86-C-2422.

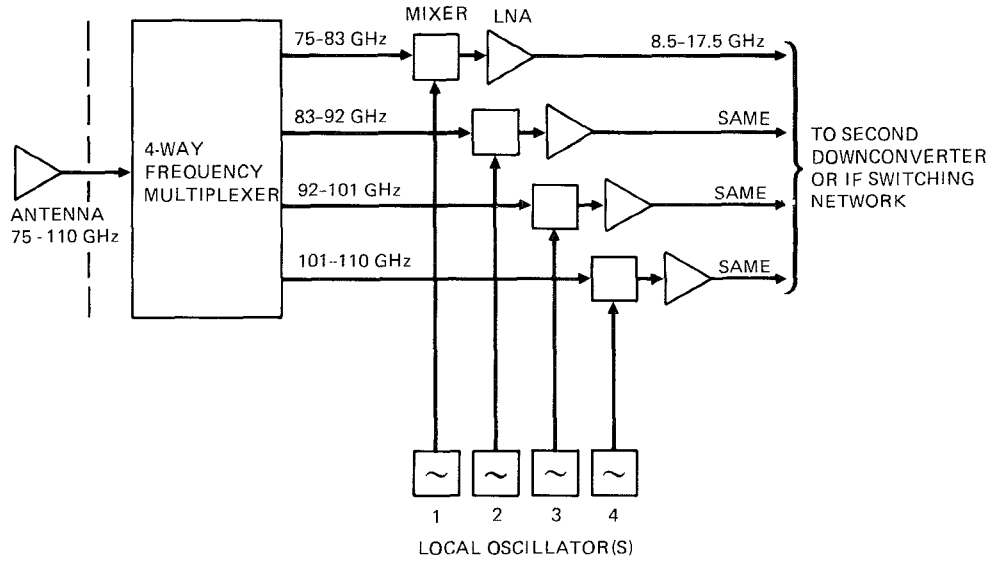

Figure 1 Block diagram of the W-band channelized monolithic receiver.

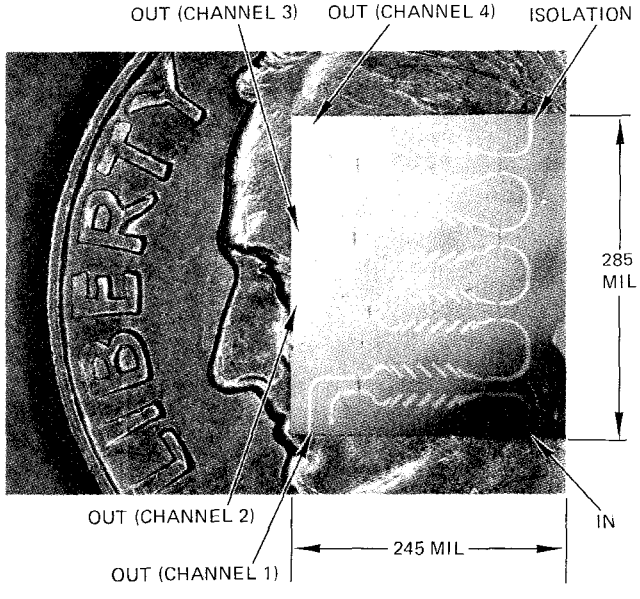

Figure 2 W-Band (75 to 110 GHz) four-channel monolithic multiplexer.

Broadband, Low Noise IF Amplifier

A wideband monolithic low noise IF amplifier using production adaptable MMIC techniques has been developed.[2] Figure 6 is a photograph of the fabricated amplifier chip. The dimensions of the chip are 2.5 x 3.3 x 0.1 mm. The amplifier has greater than 22 dB gain with less than 4.5 dB noise figure from 7.5 to 17 GHz, as shown in Figure 7.

Monolithic Gunn Local Oscillators

A local oscillator is a critical component for the W-band channelized monolithic receiver. It should provide at least 10 mW of CW power at W-band frequencies, with high spectral purity, and be capable of monolithic fabrication. We developed a novel, flip-chip monolithic Gunn oscillator technique, which achieved state-of-the-art performance. Figure 8 is a schematic diagram of the monolithic Gunn oscillator. In this design, the Gunn diode is directly sitting on the big heat sink and, therefore, the heat dissipation problem is resolved. Figure 9 shows a complete GaAs monolithic Gunn oscillator chip. We achieved 7.7 dBm of output power at 96 GHz, 11.3 dBm of output at 72 GHz, and 13 dBm of output at 63 GHz. The frequency spectra of the monolithic Gunn oscillator were very clean. A typical frequency spectrum is shown in Figure 10.

Monolithic Channelized Receiver Integration

The fabricated MMIC components will be integrated into a wideband monolithic receiver front end using only three chips. Figure 11 is a schematic diagram of the three-chip monolithic receiver. It consists of a four-channel downconverter chip and two dual-channel local oscillator chips. The dual-channel oscillator chip employs two flip-chip monolithic Gunn local oscillators. The downconverter chip with dimensions of 380 x 400 mils employs one four-channel multiplexer, four balanced mixers, and four IF amplifiers. To do this, we must fabricate FETs and Schottky diodes on the same wafer. Multiple ion doses and energies will be selectively implanted into a LEC substrate to form the active areas for the FETs and diodes. Another important feature of the W-band single-chip four-channel downconverter is the cross-overs. To minimize coupling between transmission lines, we used a narrow bridge for IF signals to cross over the W-band LO transmission lines. We are currently fabricating these three monolithic submodule chips and a test fixture to facilitate the four-channel receiver evaluation.

CONCLUSION

Monolithic integrated circuit components using production adaptable MMIC techniques have been successfully developed for a W-band four-channel monolithic receiver.

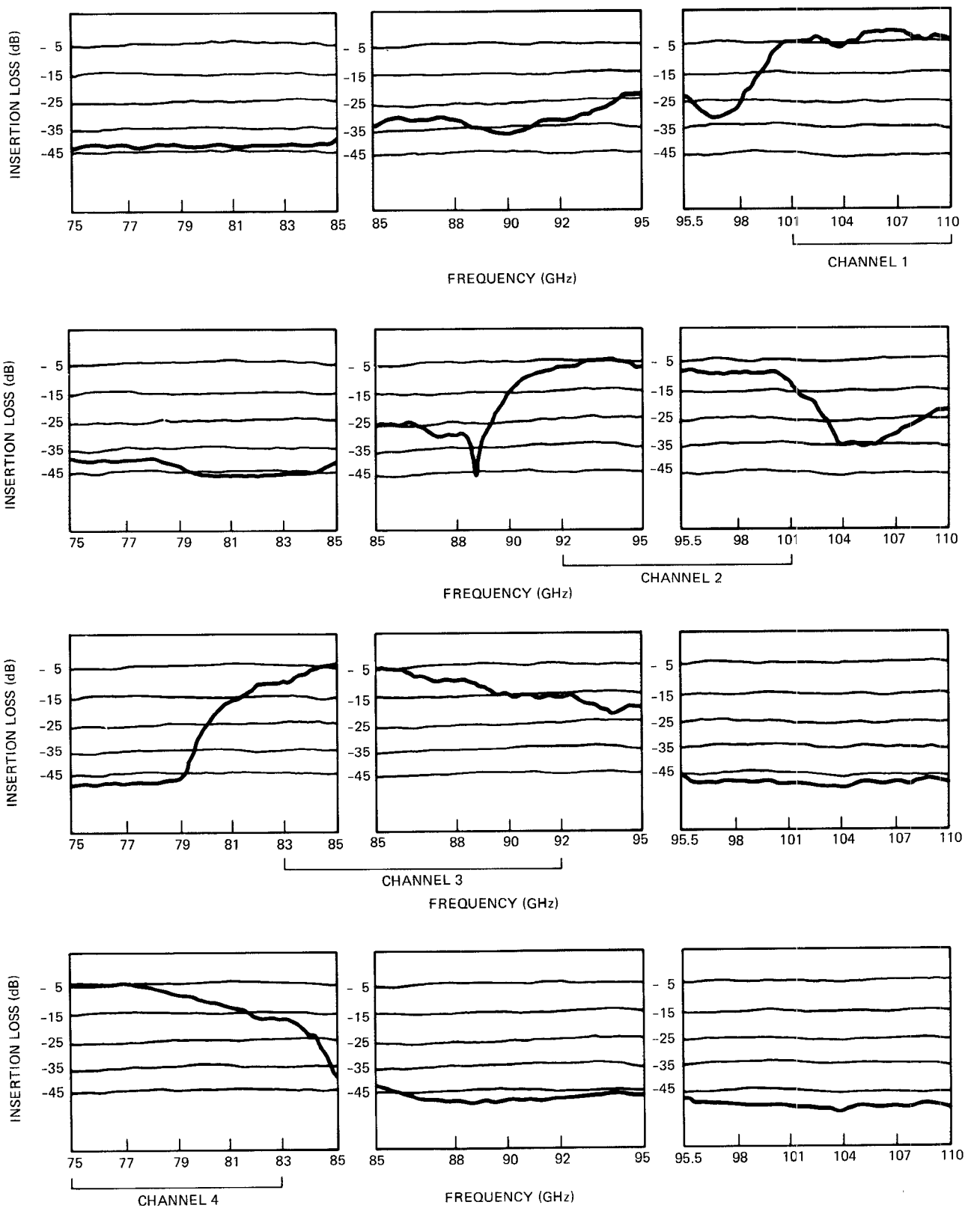

Figure 3 Performance for the W-band monolithic multiplexer.

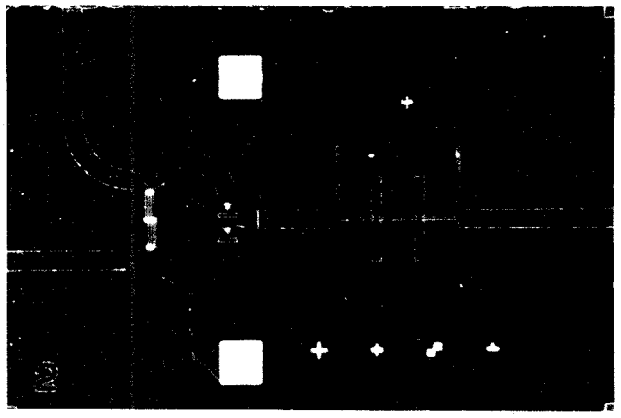

Figure 4 Ion-implanted W-band monolithic balanced mixer.

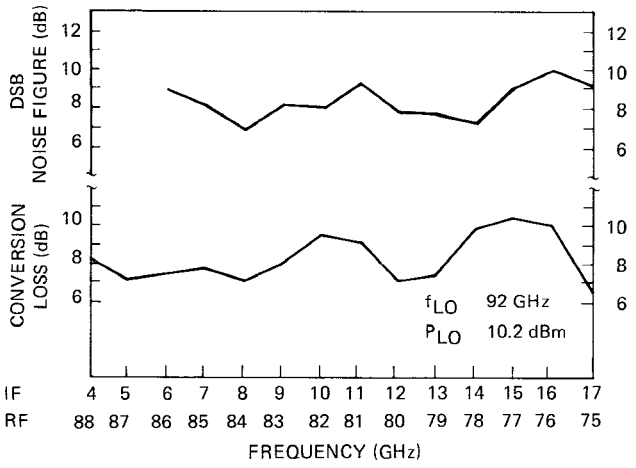

Figure 5 Typical performance of the ion-implanted W-band monolithic mixer.

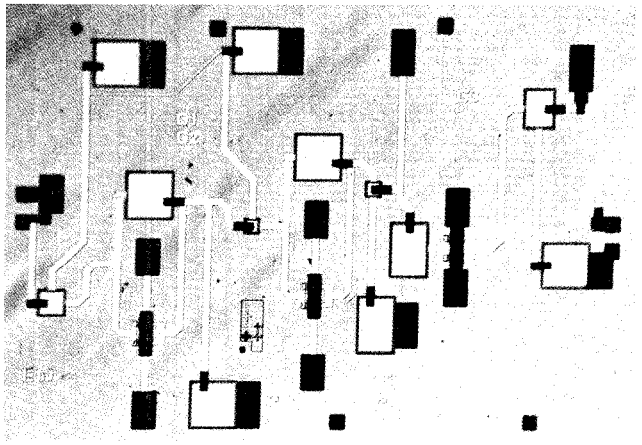

Figure 6 Photograph of the monolithic low-noise IF amplifier.

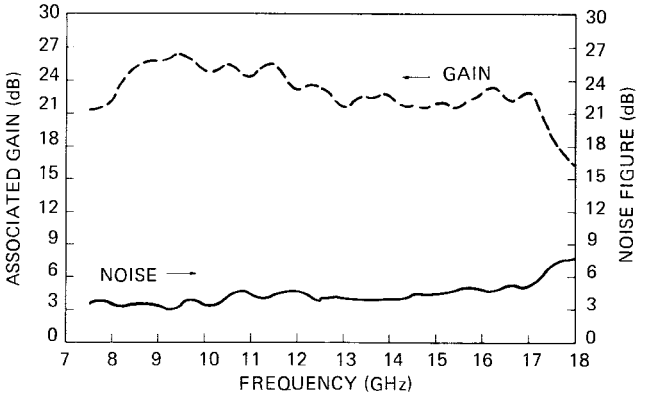

Figure 7 Performance of the wideband IF amplifier.

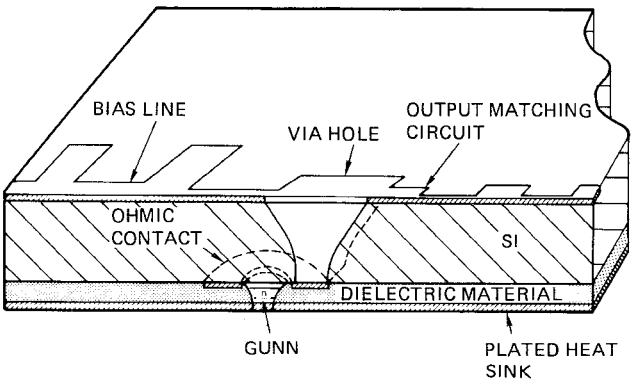

Figure 8 Schematic diagram of the monolithic Gunn oscillator.

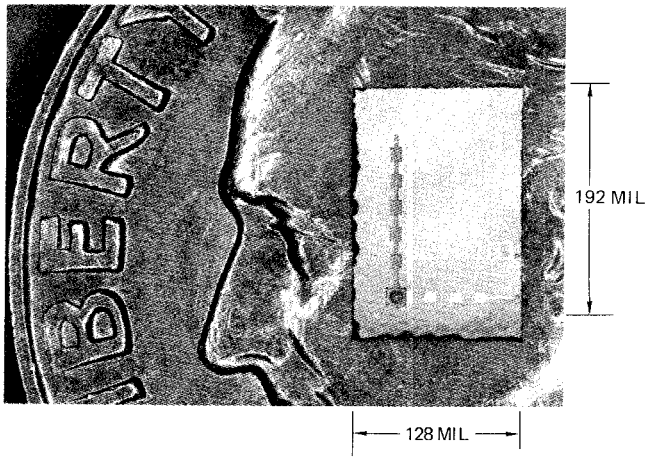

Figure 9 W-band GaAs monolithic Gunn oscillator.

State-of-the-art performance includes 5 dB insertion loss and 25 dB rejection for a W-band, four-channel monolithic multiplexer, less than 10 dB conversion loss over 13 GHz bandwidth for W-band ion-implanted mixers, and 13 dBm output at

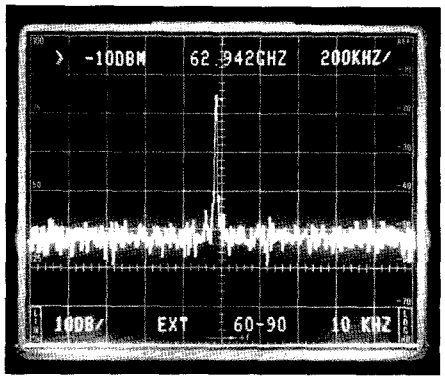

Figure 10 Typical frequency spectrum of a monolithic Gunn oscillator.

63 GHz and 7.7 dBm at 96 GHz for monolithic Gunn oscillators. The developed MMIC components will be monolithically fabricated on only three chips for a wideband channelized receiver front end.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. H. J. Kuno and Mr. R. S. Ying for their support and guidance. This paper is based upon work performed at Hughes Aircraft Company under the sponsorship of the Naval Research Laboratory. Many colleagues at Hughes have contributed and/or provided material presented here. Their help is gratefully acknowledged.

REFERENCES

1. T.N. Trinh, W.S. Wong, D. Li, and J.R. Kessler, "Ion Implanted W-Band Monolithic Balanced Mixers for Broadband Applications," 1987, IEEE Microwave Millimeter-Wave Monolithic Circuits Symposium Digest, pp 89-92.

2. C.S. Liu, K.G. Wong, and C.D. Chang, "A 6 to 18 GHz Monolithic Low Noise Amplifier," 1987, IEEE GaAs IC Symposium Digest, pp 211-214.

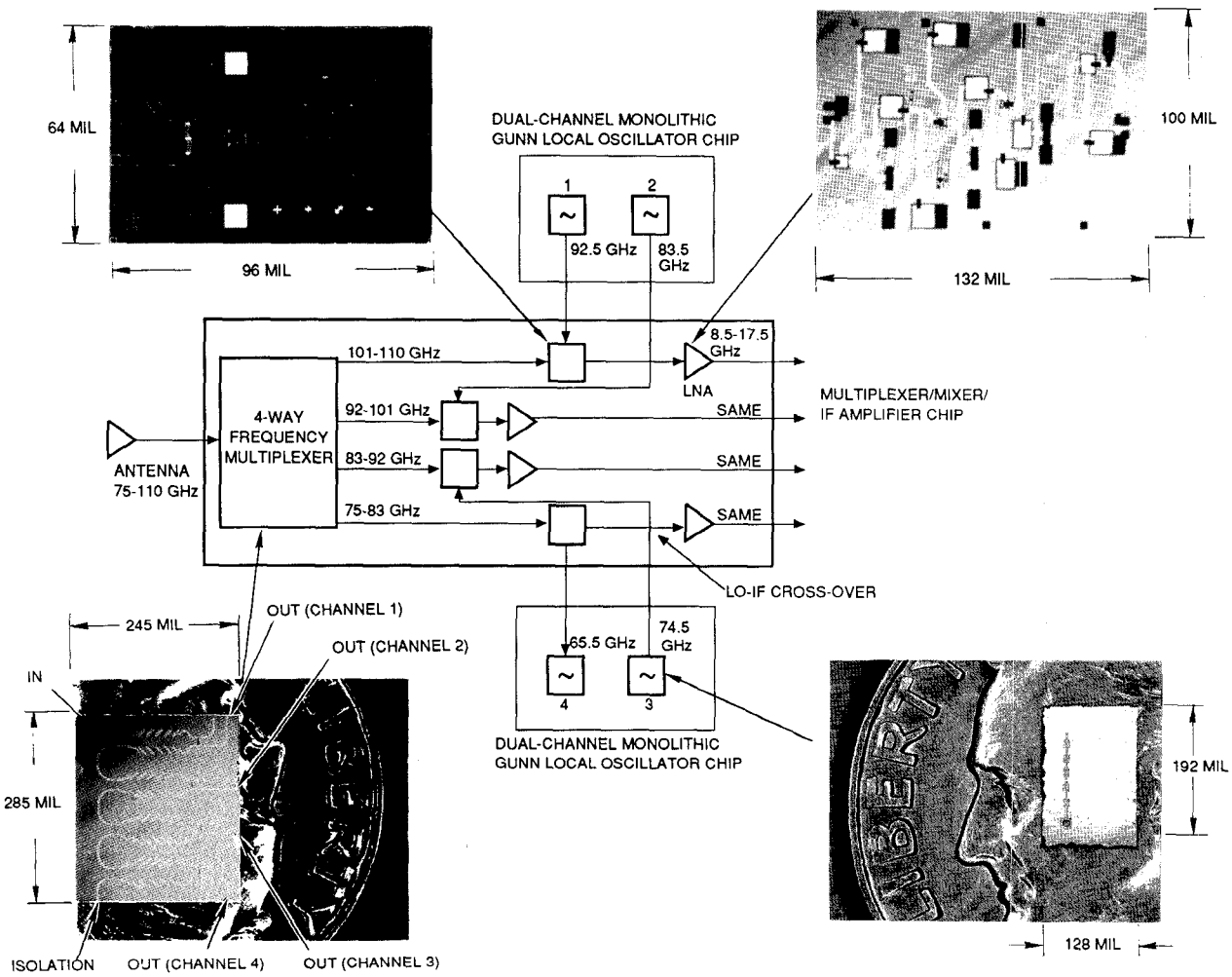

Figure 11 W-band channelized monolithic receiver integration using only three chips.